PROCEEDINGS OF THE TWENTY-SEVENTH ANNUAL KECK RESEARCH SYMPOSIUM IN GEOLOGY

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Faculty: *ROB STERNBERG*, Franklin & Marshall College, *JOSHUA FEINBERG*, Univ. Minnesota, *STEVEN SHACKLEY,* Univ. California, Berkeley, *ANASTASIA STEFFEN*, Valles Caldera Trust, and Dept. of Anthropology, University of New Mexico
Students: *ALEXANDRA FREEMAN*, Colorado College, *ANDREW GREGOVICH*, Colorado College, *CAROLINE HACKETT*, Smith College, *MICHAEL HARRISON,* California State Univ.-Chico, *MICHAELA KIM*, Mt. Holyoke College, *ZACHARY OSBORNE*, St. Norbert College, *AUDRUANNA POLLEN*, Occidental College, *MARGO REGIER*, Beloit College, *KAREN ROTH*, Washington & Lee University

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Students: *BRIAN FRETT*, Carleton College, *KATE KAMINSKI*, Union College, *BRIANNA RICK*, Carleton College, *MEGHAN RIEHL*, Union College, *CLAUDIA ROIG*, Univ. of Puerto Rico, Mayagüez Campus, *ADRIAN WACKETT*, Trinity University,

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Students: *LUCY ANDREWS*, Macalester College, *AMY DELBECQ*, Beloit College, *SAMANTHA DOW*, Univ. Connecticut, *CATHERINE DUNN*, Oberlin College, *WESLEY JOHNSON*, Univ. Massachusetts, *RACHEL JOHNSON,* Carleton College, *SCOTT KUGEL*, The College of Wooster, *AIDA OROZCO*, Amherst College, *JULIA SEIDENSTEIN,* Lafayette College

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Research Advisor: Anna M. Martini

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CLAY MINERALOGY FINGERPRINTING OF SEDIMENTS DEPOSITED FROM TROPICAL STORM IRENE IN THE CONNECTICUT RIVER WATERSHED

JULIA SEIDENSTEIN, Lafayette College
Research Advisor: Dru Germanoski

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EVALUATING EXTREME WEATHER RESPONSE IN THE CONNECTICUT RIVER FLOODPLAIN ENVIRONMENT

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BRIAN YELLEN, University of Massachusetts

INTRODUCTION

Understanding how sediment is transported, trapped, and remobilized in low-lying rivers and respective estuaries is of broad geomorphic significance, fundamental to quantifying river inputs to the ocean, constraining internal inventories, and predicting the evolution of low gradient landscapes. However, the building of flood control dams and increased frequency of extreme weather events associated with climate change may be changing the way sediment is transported through these alluvial systems. In this project, we evaluated the impact of Tropical Storm Irene on sediment transport through the lower part of the Connecticut River Watershed.

TROPICAL STORM IRENE

The remnants of Hurricane Irene passed directly over the northeastern United States between August 28th and 29th of 2011. Flooding during the event was particularly severe within the upland tributaries of the Connecticut River, including the Deerfield River (Fig. 1), where record-breaking rainfall totals ranged from 180-250 mm, (>2% exceedance probability, USDA, 1977). Peak upland flows during Irene were similar for the Deerfield River and the Connecticut River above the Deerfield confluence at N. Walpole, NH; with the two rivers cresting at record-breaking discharges of 3100 m^3/s and 2800 m^3/s, respectively. The initial peak in discharge from the Deerfield River is estimated to have entered the Connecticut River near Montague, MA on August 28th, followed roughly 1.4 days later by peaking flows from the Upper Connecticut at N. Walpole. Two chronologically distinct peaks in turbidity are evident downstream towards the mouth of the river at Middle Haddam, CT and Essex, CT (Fig. 2). These two peaks exhibit a similar 1.4 day lag between them, a finding consistent with sediment introduction first during cresting conditions for the smaller Deerfield tributary followed by maximum loads introduced above the Deerfield confluence during peak discharge in the upper Connecticut River at N. Walpole.

Tropical storm Irene was an anomaly with respect to sediment delivered to the river system. By concentrating the heaviest precipitation in the mid to upper reaches of the river, Irene remobilized significant glacial-lacustrine sediments and

Figure 1. Tropical Storm Irene caused record high discharge on the Deerfield River observed here at the Bridge of Flowers in Shelburne Falls, Massachusetts.

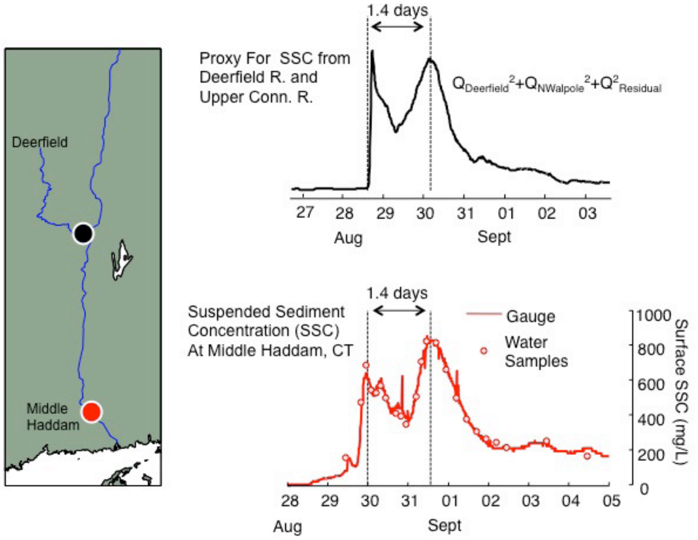
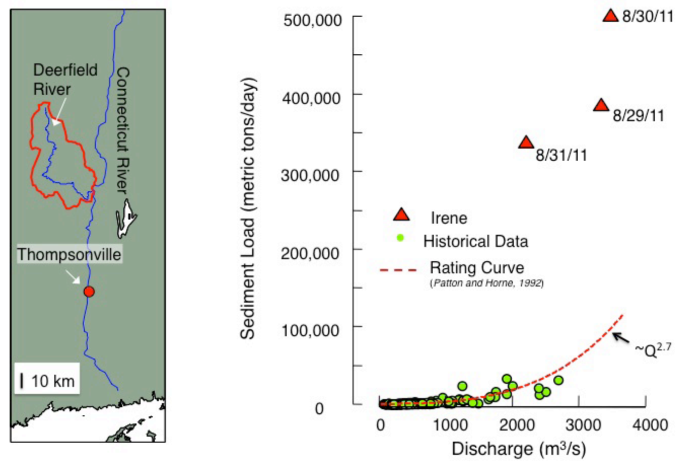


Figure 2. Upland contributions for sediment load to the lower river. The top discharge curve for hurricane Irene show two peaks, the first for the Deerfield, and the second for the Upper Connecticut River watershed. The lower plot of SSC shows a similar double peak with an identical time lag between peaks.



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dramatically “redrew” the sediment ratings curve for the Connecticut River (Fig. 3).

The sediment load was not only increased, but its character (both grain size and composition) changed. Irene’s “unique” sedimentary fingerprint strongly suggests the addition of glacial fines – a deposit with lower organic matter content, finer grain size, increased K, decreased Zr, and lower Hg content (Fig. 4). The lower Hg concentrations one might expect from both lower organic content (as Hg is often bound to OM) and the implied source material (glacial fines).

This change in the character of the sediment may be due to one watershed in particular, (i.e. the Deerfield River) which seems to contribute far more than its fair share to the overall sediment burden. The Deerfield River, with its far more limited dam controlled tributaries, is overrepresented in the suspended sediment records of the Irene event (Fig. 3). The main sediment pulse from the event took approximately one and a half days to reach the mouth of the river. At Middle Haddam, turbidity was monitored at 3-hours intervals throughout the storm. Two peaks in suspended sediment concentration (SSC) are noted. The lag between the two is of equal duration (~1.4 days) to the lag in peak discharge for the Deerfield versus the upper Connecticut River watershed. We contend that the discharge can be used as a simple proxy for the same difference in intervals of sediment load downstream. With this in mind, the Deerfield represents on its own as much as 40% of the suspended sediment, while it only makes up ~5% of the watershed.

PROJECT OVERVIEW

A major goal of this project was to locate and characterize sediments from a variety of depositional settings deposited during Tropical Storm Irene. At the beginning of the project we looked at the sources of sediment in the Deerfield River watershed where Irene spawned a series of mass wasting events ranging from rotational slips in glacial lake clay sediments to debris avalanches of till moving along steep bedrock surfaces (Fig. 4). Bank erosion, especially at channel bends, was impressive with cut banks in some locations being more than 10-20m high. The nature of the source material was highly variable, ranging from relatively coarse grained sandy till with little mud sized fraction (Upper Till), to much more massive fine grained till (Lower Till) and glacial lake sediments that are composed of more than 50% silt and clay sized material. While the Deerfield River watershed experienced some of the most impressive flooding and erosion during Irene, the watershed lacked many natural or manmade sites where fine-grained sediments could be deposited.

One potential depositional site is the Sherman Reservoir, located on the Vermont, Massachusetts border that was built in 1927 to produce hydroelectric power. Lucy Andrews collected and analyzed a series of push cores in an attempt to identify and characterize the Irene sediments at this location. It was expected that this site would produce a well-defined Irene layer as it is located in the heart of the zone most affected by the storm. However, none of the cores showed any sediment with Irene characteristics. Lucy has proposed several hypotheses to explain this lack of sediment. The most likely is that the Harriman Reservoir, located just 10km upstream, trapped much of the sediment before it reached the Sherman Reservoir.

Sediment production in the Deerfield River watershed is in part a function of the nature of the materials in the watershed. Samantha Dow examined sediment accumulation behind a small dam on the South River, a tributary to the Deerfield located near Conway Massachusetts. Early settlers in this region relied heavily on water stored behind small dams to power mills of various kinds. At the same time, sediment production within the watershed increased as settlers cut the forests and converted most of the land to fields and pasture. Most of the early dams are gone releasing the sediment that had accumulated behind them. Samantha looked at sediment accumulation behind the Conway Electric Reservoir dam. This structure was constructed around 1900 to provide hydropower for a local trolley line. Today the reservoir is completely filled with sediment. Samantha collected a series of vibracores near the dam and used air photo and Lidar data to determine the history of sedimentation behind the dam. Sediment production in this watershed is influenced by the surficial geology. The north flowing South River was blocked by the retreating ice front during deglaciation. This caused much of the valley to be filled by ice marginal lake sediments that are mostly well-sorted fine-grained sands. This material was easily mobilized and rapidly filled artificial impoundments.

Because of the lack of slack water deposition sites in the Deerfield, the project examined sedimentation at a number of nearby sites within the neighboring watersheds. The Westfield River watershed lies directly south of the Deerfield and it too experienced very high precipitation and record peak flooding from Irene. There are two flood control dams in the watershed, one on the East Branch (Knightville Dam) and the other on the Middle Branch (Littleville Dam). Knightville Dam is a 160ft high earthen structure that only holds back water during storm or snowmelt events. At other times the river freely flows through the base of the dam. Littleville Dam is approximately the same size but a 1.11km^2 30m deep lake is maintained just upstream of the dam. Two students examined the sediments within Littleville Lake to determine how much sediment collected in the lake during the Irene event. Rachel Johnson looked at the delta that has formed since the lake was created in 1965. She used a variety of techniques including bathymetric mapping, ground penetrating radar and a series of sediment cores to define and map delta facies. Analysis of the volume of sediment deposited since the lake formed, suggests that the average sediment yield of this watershed is low compared to other watersheds in the area. Not surprisingly, the coarse sediments of the delta did not provide a unique sedimentary signature for the Irene event.

Katie Dunn examined sediments from the deeper part of Littleville Lake. She found that fine-grained sediments were not pervasive on the lake floor but were limited to some of the deeper areas. She collected a series cores using both a gravity corer and push cores. However, due to the hardness of the lake bottom, she successfully collected sediment at only 10 of 56 coring locations. Cores were analyzed at the Quaternary Lab at the University of Massachusetts using a variety of techniques to identify Irene sediments. The Irene layer was identified based on its gray color together with its characteristic high potassium and low zirconium concentrations and high density. Samples collected from the Irene layer were also analyzed by Julia Seidenstein who did a comparative clay mineralogy study that showed that these Irene sediments have the same characteristic clay mineral signature that is found at other locations.

Amy Delbecq examined sediments within the flood pool of the Knightville dam. She collected cores extending upstream several kilometers from a small isolated pool directly at the base of the dam. Sedimentary event layers were identified on the basis of changes in grain size, organic content and mercury concentrations. Although the Irene layer was identifiable in these cores it was hard to differentiate from the normal sedimentary pattern that occurs in this reservoir that only holds water for a short time after hydrologic events.

The thickest and best developed Irene deposit came from the Ball Mountain Reservoir in Jamaica Vermont. Wesley Johnson collected a series of cores that contain a 10cm thick relatively fine layer that has anomalously high potassium, low strontium, and low organics. This is very similar to Irene deposits that have been identified in numerous embayments along the Connecticut River Watershed (Keeney Cove). Wes used his data to compare the sediment yield of the Ball Mountain watershed to that of the Deerfield and Connecticut rivers. He found that the amount of sediment trapped in this flood control reservoir was relatively low compared to these other areas and likely shows that flood control reservoirs are not very efficient traps of fine-grained sediments during extreme weather events.

Fine-grained sediments from Tropical Storm Irene appear to be derived from relatively unweathered glacial sediments compared to the more weathered material transported through the fluvial floodplain system. If some of the sediment was derived from the erosion of surface soils, it might be expected that it would have relatively high concentrations of mercury derived from atmospheric deposition associated with the Industrial Revolution. Scott Kugel analyzed mercury data from cores across all the study sites to evaluate any relationships between mercury, organic matter content and grain size across the Irene deposits. The Irene deposits, being reworked glacial till, often represent a layer of low anthropogenic signals (whether industrial Hg and Pb, or nutrient loading from land use changes). Also examining the soil/organic matter fraction deposited was Aida Orozco, who used an 8-meter core from an embayment along the Connecticut to look for signs of past Hemlock forest die-offs to quantify their effects on local water bodies. Today, the combination of intense storms, warming land and present Hemlock predation by the Woolly Adelgid make these past events relevant, as we should expect similar, if not worsening, eutrophication.

Julia Seidenstein compared the clay mineralogy of Irene, pre-Irene, and post-Irene sediments from the cores, with potential source material tills from the Tuttle Brook area of the Westfield River watershed. She found that the Irene sediments are primarily composed of fresh illite and chlorite, compared to a chlorite, vermiculite, illite assemblage in the pre-and post-Irene sediments. This reflects the weathering of chlorite and trioctahedral illite to vermiculite. Julia developed a method to quantify the relative weathering in a sediment sample based on the ratio of the 14Å to 10Å peaks for the air-dried samples on the x-ray diffractogram. Her results show that fine-grained Irene sediments deposited the Connecticut River Watershed, from Ball Mountain Reservoir in Vermont to Keeney Cove in Connecticut, were all derived from unweathered Pleistocene parent materials. Her results also show that sediments deposited since Tropical Storm Irene include an Irene component showing that these extreme event deposits are still in transit through the fluvial system.

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